UKTAG RIVER ASSESSMENT METHODS
MACROPHYTES AND PHYTOBENTHOS

MACROPHYTES (RIVER LEAFPACS)

by
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It is also the responsibility of the user if seeking to practise the method outlined here, to gain appropriate permissions for access to water courses and their biological sampling.

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1 Introduction

This method statement describes a monitoring system for monitoring, assessing and classifying rivers in accordance with the requirements of Article 8; Section 1.3 of Annex II; and Annex V of the Water Framework Directive (2000/60/EC).

1.1 Geographic application of the method

The method can be applied to rivers in England, Scotland, Wales and Northern Ireland.

1.2 Quality element assessed by the method

The method enables an assessment of the condition of part of the quality element, "macrophytes and phytobenthos", listed in Table 1.2.1 of Annex V to the Water Framework Directive

1.3 Pressures to which the method is known to be sensitive

The method has been designed to detect the impact on the quality element of nutrient enrichment, alterations to river flows and modifications to morphological conditions. It is also known to be sensitive to other pressures or combinations of pressures.

1.3 Parameters used to assess the quality element

The method assesses the condition of the quality element by combining information on the parameters listed below. The parameters are calculated using information on macrophyte species and groups of such species. The results for each parameter are then used to produce an ecological quality ratio for the combined parameters. The combined parameters are referred to as River LEAFPACS.

(i) River Macrophyte Nutrient Index (RMNI);
(ii) River Macrophyte Hydraulic Index (RMHI);
(iii) number of macrophyte taxa which are not helophytes (NTAXA);
(iv) number of functional groups of macrophyte taxa which are not helophytes (NFG); and
(v) Percentage cover of green filamentous algae (ALG)

2 Sampling and analysis

In order to obtain the data with which to calculate the observed values for each of the parameters, 100 metre stretches of the river should normally be sampled between 1st

June and 30th September. Sampling should not be undertaken during periods of high flows. Where cold weather or spring floods may have delayed the growth of macrophyte taxa, sampling should commence after 30th June.

Surveying should establish the presence, and percentage of the river channel covered by, each of the macrophyte taxa listed in column 1 of Table 1. Where it is not possible to identify a macrophyte present in the river to species level, it should be recorded under its genus or other aggregate taxon level if such is listed in column 1 of Table 1.

Each taxon present in the river and listed in Column 1 of Table 1 should be assigned the taxon cover value in Column 2 of Table 2 which corresponds to the percentage cover range in Column 1 of that table within which the percentage cover of the taxon in the river lies.

The survey method used should conform to CEN 14184 : 2003 Water quality – Guidance standard for the surveying of aquatic macrophytes in running waters.

3 Procedure for deriving the ecological quality ratio for the parameters

3.1 Calculation of the observed value for each parameter

(i) River Macrophyte Nutrient Index (RMNI)

In order to calculate the observed value of the parameter, RMNI, each macrophyte taxon listed in Column 1 of Table 1 and identified as being present in the river should be assigned the corresponding river macrophyte nutrient index score in Column 2 of that Table.

The observed value of the parameter, RMNI, should be calculated using the equation:

$$\text{Observed value of RMNI} = \frac{\sum_{j=1}^{n} (C_j \times R_j)}{\sum_{j=1}^{n} C_j}$$

where:
"R_j" is the river macrophyte nutrient index score in Column 2 of Table 1 for taxon "j";
"j" represents a taxon listed in Column 1 of Table 1, present in the sample and with a value listed in Column 2 of Table 1. "j" has a value of 1 to "n" indicating which of the all the taxa (total number = "n") listed in Column 1 of Table 1 and present in the sample it represents; and
"C_j" is the taxon cover value for taxon "j" determined in accordance with Section 2 and Table 2.

(ii) River Macrophyte Hydraulic Index (RMHI)

In order to calculate the observed value of the parameter, RMHI, each macrophyte taxon listed in Column 1 of Table 1 and identified as being present in the river should be assigned the corresponding river macrophyte hydraulic index score in Column 3 of that Table.

The observed value of the parameter, RMHI, should be calculated using the equation:

$$\text{Observed value of RMHI} = \frac{\sum_{j=1}^{n} (C_j \times H_j)}{\sum_{j=1}^{n} C_j}$$

where:
"H_j" is the river macrophyte hydraulic index score in Column 3 of Table 1 for taxon "j";
"j" represents a taxon listed in Column 1 of Table 1 , present in the sample and with a value listed in Column 3 of Table 1. "j" has a value of 1 to "n" indicating which of the all the taxa (total number = "n") listed in Column 1 of Table 1 and present in the sample it represents; and
"C_j" is the taxon cover value for taxon "j" determined in accordance with Section 2 and Table 2.

(iii) Number of macrophyte taxa which are not helophytes (NTAXA)

The observed value for the parameter, NTAXA, is given by the sum of the number of taxa listed in Column 1 of Table 1 that are present in the river and identified in Column 4 of that Table as not being helophytes. Note, that when there are morphologically distinct taxa present belonging to a single aggregate (e.g. *Ranunculus* section *Batrachian*), no members of which can be identified to species level, these should be recorded as separate species for the purposes of calculating this metric.

(iv) Number of functional groups of macrophyte taxa which are not helophytes (NFG)

In order to calculate the observed value for the parameter, NFG, each taxon listed in Column 1 of Table 1, identified in Column 4 of that Table as not being helophytes and present in the river should be assigned to the corresponding macrophyte functional group number in Column 5 of Table 1.

The observed value for the parameter, NFG, is given by the sum of the number of different functional groups of taxa identified as present in the river.

(vi) Percentage cover of green filamentous algae (ALG)

To calculate the observed value of the parameter ALG add up the individual percentage cover of all taxa in Column 1 of Table 1 which bear the suffix ‘A’. To derive percentage cover use the mid point of the percentage cover range associated with each taxon cover

score, as indicated in column 3 of Table 2. A direct visual assessment of the overall percentage cover of green filamentous algae at the site is an acceptable alternative.

The Observed value for the parameter ALG represents the total coverage of the stream bed by green filamentous algae and will range from 0-100.

3.2 Calculation of the reference value for each parameter

The reference values described below for each parameter were derived using a combination of (a) information from a network of river sites identified as being subject to no or very minor alterations likely to affect their macrophyte communities and (b) modelling.

(i) River Macrophyte Nutrient Index (RMNI)

The value for the parameter, RMNI, in the reference conditions applicable to the river should be calculated using the following equation:

$$\text{Reference value for RMNI} = 3.427276 + [1.812963 \times \text{Log}_{10}(\text{Alk} + 1)] + [-0.80437 \times \text{Log}_{10}(\text{S}+1)] + [0.595212 \times \text{Log}_{10}(\text{D} + 1)] + [-0.0047 \times \text{Alk}] + [-0.52502 \times \text{Log}_{10}(\text{hSo} + 1)] + [0.010299 \times \text{S}]$$

If the resulting reference value for the parameter, RMNI is greater than 7.2 then a reference value of 7.2 should be assigned

(ii) River Macrophyte Hydraulic Index (RMHI)

The value for the parameter, RMHI, in the reference conditions applicable to the river should be calculated using the following equation:

$$\text{Reference value for RMHI} = 6.55833 + [0.664862 \times \text{Log}_{10}(\text{Alk} + 1) + [-0.85111 \times \text{Log}_{10}(\text{S} + 1)] + [0.005868 \times \text{D}] + [-0.64038 \times \text{Log}_{10}(\text{hSo} + 1) + [0.006709 \times \text{S}]$$

(iii) Number of macrophyte taxa which are not helophytes (NTAXA)

The value for the parameter, NTAXA, in the reference conditions applicable to the river should be calculated using the following equation:

$$\text{Reference value for N\_TAXA} = 10^{\text{Log}_{10}\,\text{N\_TAXA}} - 1$$

where:

$Log_{10}(NTAXA + 1) = 0.548545 + [-0.1586 \times Log_{10}(S + 1)] + [0.172477 \times Log_{10}(hSo + 1)]$

(iv) Number of functional groups of macrophyte taxa which are not helophytes (NFG)

The value for the parameter, NFG, in the reference conditions applicable to the river should be calculated using the following equation:

$$\text{Reference value for N\_FG} = 10^{Log_{10} N\_FG} - 1$$

where, for rivers in England, Scotland and Wales:

$Log_{10}(NFG + 1) = 0.785064 + [-0.1625 \times Log_{10}(S + 1)] + [0.000000143 \times N]$

and, for rivers in Northern Ireland:

$Log_{10}(NFG + 1) = 0.813705 + [-0.12266 \times Log_{10}(S + 1)]$

where, in the above equations:
"Alk" is the annual mean reference alkalinity for the river expressed as a concentration of $CaCO_3$ in mg/l;
"hSo" is the altitude in metres above mean sea level of the furthest upstream point of any tributary of the river shown on a 1:50,000 scale map;
“hSi” is the altitude in metres above mean sea level of the survey site;
"N" means the latitude of the sampled part of the river; using the coordinates of the Ordnance Survey GB grid;
"S" is the drop in altitude in metres per kilometre between the altitude of the upstream and downstream ends of sampled part of the river; and
"D" is the distance in kilometres from the upstream end of the sampled part of the river to the furthest upstream point of any tributary shown on a 1:50,000 scale map.

(v) Percentage cover of green filamentous algae (ALG)

The cover of green filamentous algae in reference sites could not be modelled satisfactorily using the environmental predictors used to model the composition and richness metrics. Consequently a global reference value of 0.05% cover is used. This is based on the median ALG value of the population of reference sites.

3.3 Calculation of the ecological quality ratio (EQR) for each parameter

(i) River Macrophyte Nutrient Index (RMNI)

The ecological quality ratio for the parameter, RMNI, should be calculated using the following equation:

EQR_{RMNI} = (observed value of RMNI – worst possible RMNI) ÷ (reference value for RMNI – worst possible RMNI)

Where worst possible RMNI, for rivers with a Reference value for RMNI of ≥4.765, is equal to 10, and for rivers with Reference RMNI of <4.765 is equal to Reference RMNI * 1.26 + 4.

(ii) River Macrophyte Hydraulic Index (RMHI)

The ecological quality ratio for the parameter, RMHI, should be calculated using the following equation:

EQR_{RMHI} = (observed value of RMHI - worst possible RMHI) ÷ (Reference value of RMHI - worst possible RMHI)

Where worst possible RMHI, for rivers with a Reference value for RMHI of ≥6.695, is equal to 10, and for rivers with Reference RMHI of <6.695 is equal to Reference RMHI * 1.18 + 2.1.

(iii) Number of macrophyte taxa which are not helophytes (NTAXA);

The ecological quality ratio for the parameter, NTAXA, should be calculated using the following equation:

$EQR_{NTAXA} = Log_{10}$[observed value of NTAXA + 1] ÷ Log_{10}[reference value for NTAXA + 1]

(iv) Number of functional groups of macrophyte taxa which are not helophytes (NFG)

The ecological quality ratio for the parameter, NFG, should be calculated using the following equation:

$EQR_{NFG} = Log_{10}$[observed value of NFG + 1] ÷ Log_{10}[reference value for NFG + 1].

(v) Percentage cover of green filamentous algae (ALG)

The ecological quality ratio for the parameter, ALG, should be calculated using the following equation:

EQR_{ALG} = (observed value of ALG – worst possible ALG) ÷ (reference value for ALG (i.e.0.05) – worst possible ALG)

Where the worst possible ALG = 100.

3.4 Adjustment of the ecological quality ratios for each parameter to enable calculation of the ecological ratio for the combined parameters (River LEAFPACS)

(i) River Macrophyte Nutrient Index (RMNI)

If the value calculated for EQR_{RMNI} is > 1, an adjusted EQR (^{A}EQR) for the parameter, RMNI, of $^{A}EQR_{RMNI} = 1$ should be applied.

If the value calculated for EQR_{RMNI} is < 0.25, an adjusted EQR (^{A}EQR) for the parameter, RMNI, of $^{A}EQR_{RMNI} = 0$ should be applied.

If the value calculated for EQR_{RMNI} is ≥ 0.25 and ≤ 1, an adjusted EQR (^{A}EQR) for the parameter, RMNI, should be calculated using the following equation.

$$^{A}EQR_{RMNI} = (1.333 \times EQR_{RMNI}) - 0.333$$

(i) River Macrophyte Hydraulic Index (RMHI)

If the value calculated for EQR_{RMHI} is > 1, an adjusted EQR (^{A}EQR) for the parameter, RMHI, of $^{A}EQR_{RMHI} = 1$ should be applied.

If the value calculated for EQR_{RMHI} is < 0.25, an adjusted EQR (^{A}EQR) for the parameter, RMHI, of $^{A}EQR_{RMHI} = 0$ should be applied.

If the value calculated for EQR_{RMHI} is ≥ 0.25 and ≤ 1, an adjusted EQR (^{A}EQR) for the parameter, RMHI, should be calculated using the following equation.

$$^{A}EQR_{RMHI} = (1.333 \times EQR_{RMHI}) - 0.333$$

(iii) Number of macrophyte taxa which are not helophytes (NTAXA)

If the value calculated for EQR_{NTAXA} is > 1, an adjusted EQR (^{A}EQR) for the parameter, NTAXA, of $^{A}EQR_{NTAXA} = 1$ should be applied.

If the value calculated for EQR_{NTAXA} is < 0.25, an adjusted EQR (^{A}EQR) for the parameter, NTAXA, of $^{A}EQR_{NTAXA} = 0$ should be applied.

If the value calculated for EQR_{NTAXA} is ≥ 0.25 and ≤ 1, an adjusted EQR (^{A}EQR) for the parameter, NTAXA, should be calculated using the following equation.

$$^{A}EQR_{NTAXA} = (1.333 \times EQR_{NTAXA}) - 0.333$$

(iv) Number of functional groups of macrophyte taxa which are not helophytes (NFG)

If the value calculated for EQR_{NFG} is > 1, an adjusted EQR (^{A}EQR) for the parameter, NFG, of $^{A}EQR_{NFG} = 1$ should be applied.

If the value calculated for EQR_{NFG} is < 0.25, an adjusted EQR (^{A}EQR) for the parameter, NFG, of $^{A}EQR_{NFG} = 0$ should be applied.

If the value calculated for EQR_{NFG} is ≥ 0.25 and ≤ 1, an adjusted EQR (^{A}EQR) for the parameter, NFG, should be calculated using the following equation.

$$^{A}EQR_{NFG} = (1.333 \times EQR_{NFG}) - 0.333$$

(v) Percentage cover of green filamentous algae (ALG)

If the value calculated for EQR_{ALG} is > 0.975, an adjusted EQR (^{A}EQR) for the parameter, ALG, should be calculated using the following equation.

$$^{A}EQR_{ALG} = ((EQR_{ALG} - 0.975) \div (1 - 0.975)) \times 0.2 + 0.8,$$

If the value calculated for EQR_{ALG} is ≥ 0.925 and ≤ 0.975, an adjusted EQR (^{A}EQR) for the parameter, ALG, should be calculated using the following equation.

$$^{A}EQR_{ALG} = ((EQR_{ALG} - 0.925) \div (0.975-0.925)) \times 0.2 + 0.6,$$

If the value calculated for EQR_{ALG} is ≥ 0.825 and ≤ 0.925, an adjusted EQR (^{A}EQR) for the parameter, ALG, should be calculated using the following equation.

$$^{A}EQR_{ALG} = ((EQR_{ALG} -0.825) \div (0.925-0.825)) \times 0.2 + 0.4,$$

If the value calculated for EQR_{ALG} is ≥ 0.625 and ≤ 0.825, an adjusted EQR (^{A}EQR) for the parameter, ALG, should be calculated using the following equation.

$$^{A}EQR_{ALG} = ((EQR_{ALG} - 0.625) \div (0.825 - 0.625)) \times 0.2 + 0.2,$$

If the value calculated for EQR_{ALG} is < 0.625, an adjusted EQR (^{A}EQR) for the parameter, ALG, should be calculated using the following equation.

$$^{A}EQR_{ALG} = (EQR_{ALG} \div 0.625) \times 0.2$$

3.5 Combining the ecological quality ratios for the different parameters

The ecological quality ratio for the combined parameters ($EQR_{LEAFPACS}$] should be determined as follows:

Step 1:
If the smaller of the values calculated for $^{A}EQR_{NTAXA}$ and $^{A}EQR_{NFG}$ is smaller than the smaller of the values calculated for $^{A}EQR_{RMNI}$ and $^{A}EQR_{RMHI}$, the ecological quality ratio for the combined composition and diversity parameters ($EQR_{C\&D}$) should be calculated using the equation:

$$EQR_{C\&D} = ((0.5 \times [^{A}EQR_{NTAXA} \text{ or } ^{A}EQR_{NFG}, \text{whichever is the smaller}]) + [^{A}EQR_{RMNI} \text{ or } ^{A}EQR_{RMHI}, \text{whichever is the smaller}]) \div 1.5$$

If the smaller of the values calculated for $^{A}EQR_{NTAXA}$ and $^{A}EQR_{NFG}$ is larger than the smaller of the values calculated $^{A}EQR_{RMNI}$ and $^{A}EQR_{RMHI}$, the ecological quality ratio for the combined parameters should be calculated using the equation:

$$EQR_{C\&D} = (K \times [^{A}EQR_{NTAXA} \text{ or } ^{A}EQR_{NFG}, \text{whichever is the smaller}] + [^{A}EQR_{RMNI} \text{ or } ^{A}EQR_{RMHI}, \text{whichever is the smaller}]) \div (K + 1)$$

where:

"K" = 0.25 + 1 ÷ (Exp (Ln (1500) + reference RMNI x Ln (0.31)) + 1 ÷ 0.5)

"Exp" is the mathematical exponential function (e^{x}); and
"Ln" is the logarithm to the base of e.

Step 2:
If the value of $EQR_{C\&D}$ calculated in Step 1 is smaller than $^{A}EQR_{ALG}$ then $EQR_{C\&D}$ is equal to $EQR_{LEAFPACS}$.

If the value of $EQR_{C\&D}$ calculated in Step 1 is larger than $^{A}EQR_{ALG}$ then $EQR_{C\&D}$ and $^{A}EQR_{ALG}$ are combined according to the equation:

$$EQR_{LEAFPACS} = (Z \times {}^{A}EQR_{ALG} + EQR_{C\&D}) \div (Z + 1)$$

where:

"Z" = 2 x (1 ÷ (Exp (Ln (2600000000) + reference RMNI x Ln (0.0166)) + 1 ÷ 0.5)

"Exp" is the mathematical exponential function (e^{x}); and
"Ln" is the logarithm to the base of e.

$EQR_{LEAFPACS}$ represents the ecological quality ratio for the site from a macrophyte perspective..

3.5 Application of the method for the purposes of classification

When using the method for the purposes of classifying the ecological status or potential of a water body, the mean value for the ecological quality ratio ($EQR_{LEAFPACS}$) for the combined parameters should be used.

4 Glossary

"Functional group" is a group of organisms which exploit a resource in a similar way.
"Helophyte" is a plant that is usually rooted under water with emergent shoots, typically growing in marginal or marshy areas.
"Macrophytes" are larger plants of fresh water which are easily seen with the naked eye, including all vascular plants, bryophytes, stoneworts (Characeae) and macro-algal growths.

Table 1: List of river macrophyte taxa and associated information for the calculation of the values for the parameters

Column 1	Column 2	Column 3	Column 4	Column 5
Taxon	**River macrophyte nutrient index score (R)**	**River macrophyte hydraulic index score (H)**	**Taxa listed in Column 1 which are not helophytes (x)**	**Macrophyte functional group number**
Acorus calamus	9.49	9.82		
Alisma lanceolatum	8.47	9.12		
Alisma plantago-aquatica	7.82	8.02		
Anthelia julacea	2.7			
Apium inundatum	4.34	5.89	X	8
Apium nodiflorum	8.64	8.08	X	8
Azolla filiculoides	9.71	8.98	X	1
Baldellia ranunculoides	4.34	3.7	X	4
Batrachospermum sp	5.46	6.1	X	19
Berula erecta	8.24	8.17	X	8
Bidens cernua	8.13	7.9		
Bidens tripartita	8.39	8.16		
Blindia acuta	1.09	3.24	X	22
Blue-green algal scum/pelts	5.1	5.2	X	3
Bolboschoenus maritimus	7.65	8.19		
Brachythecium plumosum	2.92	3.87	X	21
Brachythecium rivulare	3.56	4.3	X	21
Bryum alpinum	3.83	3.21		
Bryum dixonii	5.22	5.65		
Bryum pseudotriquetrum	2.71	3.87		
Butomus umbellatus	8.89	8.61	X	13
Calliergon cuspidatum	3.49	3.72		
Callitriche brutia var	4.51	5.81	X	6

Table 1: List of river macrophyte taxa and associated information for the calculation of the values for the parameters

Column 1	Column 2	Column 3	Column 4	Column 5
Taxon	**River macrophyte nutrient index score (R)**	**River macrophyte hydraulic index score (H)**	**Taxa listed in Column 1 which are not helophytes (x)**	**Macrophyte functional group number**
hamulata				
Callitriche hermaphroditica	5.75	7.6	X	5
Callitriche obtusangula	8.04	7.98	X	6
Callitriche platycarpa	7.56	7.74	X	6
Callitriche sp.	6.67	7.18	X	6
Callitriche stagnalis	6.47	7.17	X	6
Callitriche stagnalis/platycarpa	6.21	6.14	X	6
Callitriche truncata	6.47	7.15	X	6
Caltha palustris	4.2	5.24		
Carex acuta	7.19	7.3		
Carex acutiformis	8.21	8.1		
Carex aquatilis	3.9	5.02		
Carex elata	4.54	6.23		
Carex lasiocarpa	3.41			
Carex paniculata	7.49	7.96		
Carex recta	5.42	6.83		
Carex riparia	9.06	8.89		
Carex rostrata	2.64	4.71		
Carex vesicaria	3.68	5.39		
Catabrosa aquatica	8.7	7.57		
Ceratophyllum demersum	9.73	9.32	X	5
Chaetophora sp.			X	
Chara globularis	3.3		X	2
Chara sp.	3.85		X	2
Chara vulgaris	3.77	5.66	X	2
Chiloscyphus pallescens	4.78	4.75		
Chiloscyphus polyanthos	4.05	4.77	X	23
Cinclidotus fontinaloides	5.37	5.68	X	22
Cladophora aegagropila	5.66	6.23	X	19
Cladophora glomerata[A]	7.5	6.84	X	19
Cladophora glomerata/Rhizoclonium hieroglyphicum[A]	8.66	7.18	X	19
Collema dichotomum	4.42	5.15	X	3
Cratoneuron filicinum	5.02	6.34		
Dermatocarpon sp	3.51	4.85		
Dichodontium flavescens	2.94	3.6		
Dichodontium palustris	1.68	3.52		

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Column 1	Column 2	Column 3	Column 4	Column 5
Taxon	**River macrophyte nutrient index score (R)**	**River macrophyte hydraulic index score (H)**	**Taxa listed in Column 1 which are not helophytes (x)**	**Macrophyte functional group number**
Dichodontium pellucidum	3.07	4.02		
Draparnaldia	3.04	2.64	X	19
Drepanocladus fluitans	3.73	4.45		
Elatine hexandra	4.17	6.15	X	11
Eleocharis acicularis	5.35	6.79	X	4
Eleocharis palustris	4.54	5.79		
Eleogiton fluitans	2.06	5.36	X	15
Elodea canadensis	7.65	7.6	X	5
Elodea nuttallii	9.44	8.62	X	5
Equisetum fluviatile	3.92	6.01		
Filamentous green algae[A]	7.61	7.04	X	19
Fisidens polyphyllus	3.84		X	22
Fissidens crassipes	6.2	6	X	22
Fissidens curnovii	3.94	5.03	X	22
Fissidens osmundoides	3.06		X	22
Fissidens rivularis	5.95	6.35	X	22
Fissidens rufulus	4.7	5.26	X	22
Fissidens serrulatus	5.27	3.39	X	22
Fissidens sp	5.8	5.94	X	22
Fissidens viridulus	4.66	5.51	X	22
Fontinalis antipyretica	5.4	5.95	X	21
Fontinalis squamosa	3.66	5.02	X	21
Glyceria declinata	6.66	6.25		
Glyceria fluitans	5.25	5.77		
Glyceria fluitans agg	5.81	6.01		
Glyceria maxima	9.64	8.96		
Glyceria notata	8.28	7.49		
Glyceria x pedicillata	7.12	7.15		
Gongrosira incrustans	7.46	5.84	X	20
Groenlandia densa	7.96	8.12	X	5
Heribaudiella fluviatilis	5.49	5.68	X	20
Hildenbrandia rivularis	6.03	6.07	X	20
Hippuris vulgaris	5.94	8.22		
Hottonia palustris	6.93	8.85	X	7
Hydrocharis morsus-ranae	8.77	9.69	X	1
Hydrodictyon reticulatum[A]	8.79	7.74	X	19
Hygroamblystegium fluviatile	5.41	5.29	X	21
Hygroamblystegium sp.	6.55	5.98	X	21

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Column 1	Column 2	Column 3	Column 4	Column 5
Taxon	**River macrophyte nutrient index score (R)**	**River macrophyte hydraulic index score (H)**	**Taxa listed in Column 1 which are not helophytes (x)**	**Macrophyte functional group number**
Hygroamblystegium tenax	5.27	5.6	X	21
Hygrobiella laxifolia	2.76	2.06	X	23
Hygrohypnum duriusculum	3.33		X	21
Hygrohypnum eugyrium	4.28	3.9	X	21
Hygrohypnum luridum	2.80	3.83	X	21
Hygrohypnum ochraceum	2.96	3.87	X	21
Hyocomium armoricum	1.96	3.6		
Hypericum elodes	2.66	4.7		
Iris pseudacorus	6.92	7.57		
Isoetes lacustris	3.02	5.9	X	4
Juncus articulatus	3.10	4.27		
Juncus bulbosus	1.89	4.35	X	4
Jungermannia atrovirens	2.28	3.62	X	23
Jungermannia exsertifolia	3.87	4.44	X	23
Jungermannia obovata	2.97	4.4	X	23
Jungermannia paroica	4.00		X	23
Jungermannia pumila	3.29	3.01	X	23
Jungermannia sp.	2.41	3.49	X	23
Jungermannia sphaerocarpa	3.08	2.48	X	23
Lemanea fluviatilis	4.51	5.26	X	19
Lemanea sp	4.53	5.17	X	19
Lemna gibba	10.00	9.14	X	1
Lemna minor	8.80	8.59	X	1
Lemna minuta	9.21	8.87	X	1
Lemna sp.	7.60	9.8	X	1
Lemna trisulca	8.21	8.66	X	1
Leptodictyon riparium	7.57	6.58	X	21
Littorella uniflora	1.96	4.84	X	4
Lobelia dortmanna	2.72	5.26	X	4
Luronium natans	4.37	5.57	X	4
Lythrum salicaria	7.33	8.11		
Marsupella aquatica	3.17	1	X	23
Marsupella emarginata	1.06	2.85	X	23
Marsupella sp.	1.24	2.75	X	23
Mentha aquatica	6.27	6.71		
Menyanthes trifoliata	3.14	5.69		
Mimulus guttatus	5.79	5.67		
Mimulus sp./hybrid	5.60	5.42		

Table 1: List of river macrophyte taxa and associated information for the calculation of the values for the parameters

Column 1	Column 2	Column 3	Column 4	Column 5
Taxon	**River macrophyte nutrient index score (R)**	**River macrophyte hydraulic index score (H)**	**Taxa listed in Column 1 which are not helophytes (x)**	**Macrophyte functional group number**
Monostroma sp.	6.86	6.43	X	3
Montia fontana	3.35	3.56		
Myosotis laxa	4.82	5.47		
Myosotis scorpioides	6.83	6.98		
Myosotis secunda	4.74	5.44		
Myosotis sp(p).	7.00	7.06		
Myriophyllum alterniflorum	3.44	5.2	X	7
Myriophyllum spicatum	8.26	7.91	X	7
Myriophyllum spp indet	5.89	6.58	X	7
Myriophyllum verticillatum	7.53		X	7
Nardia compressa	1.05	2.89	X	23
Nardia scalaris	2.73	3	X	23
Nardia sp.	1.40	3.04	X	23
Nitella flexilis (agg.)	4.39	5.56	X	2
Nitella opaca	4.31	5.1	X	2
Nitella sp	4.59	5.76	X	2
Nitella translucens	4.17	6.15	X	2
Nostoc commune	5.14	5.48	X	3
Nostoc parmelioides	4.12	4.97	X	3
Nostoc sp	4.66	5.19	X	3
Nostoc verrucosum	4.71	5.11	X	3
Nuphar lutea	8.42	9.16	X	12
Nymphaea alba	5.69	8.42	X	12
Nymphoides peltata	9.37	9.8	X	10
Octodiceras fontanum	6.54	6.7	X	22
Oenanthe aquatica	6.06	6.91	X	8
Oenanthe crocata	6.22	6.48	X	8
Oenanthe fistulosa	8.27	8.3		
Oenanthe fluviatilis	8.57	8.54	X	8
Orthotrichum rivulare	4.71	5.57		
Palustriella commutata	4.61	3.75		
Pellia endiviifolia	6.50	6.49		
Pellia epiphylla	3.34	5.09		
Pellia sp.	4.67	5.64		
Persicaria amphibia	8.20	8.33	X	10
Persicaria hydropiper	6.97	7.53		
Phalaris arundinacea	7.52	7.24		
Philonotis caespitosa	2.74	3.08		
Philonotis fontana	2.66	3.09		

Table 1: List of river macrophyte taxa and associated information for the calculation of the values for the parameters

Column 1	Column 2	Column 3	Column 4	Column 5
Taxon	**River macrophyte nutrient index score (R)**	**River macrophyte hydraulic index score (H)**	**Taxa listed in Column 1 which are not helophytes (x)**	**Macrophyte functional group number**
Phragmites australis	7.70	8.94		
Platyhypnidium lusitanicum	4.35	3.82	X	21
Platyhypnidium riparioides	5.16	5.29	X	21
Porella cordaeana	4.95	5	X	23
Porella pinnata	4.91	5.2	X	23
Potamogeton alpinus	4.96	6.26	X	16
Potamogeton berchtoldii	7.35	7.76	X	14
Potamogeton compressus	8.33	9	X	14
Potamogeton crispus	8.02	7.86	X	17
Potamogeton filiformis	6.00	7.62	X	15
Potamogeton friesii	8.19	9.09	X	14
Potamogeton gramineus	4.24	5.69	X	16
Potamogeton lucens	8.54	8.79	X	17
Potamogeton natans	5.69	7.54	X	16
Potamogeton nodosus	7.05	8.79	X	16
Potamogeton obtusifolius	5.84	6.8	X	14
Potamogeton pectinatus	9.59	8.58	X	15
Potamogeton perfoliatus	8.16	8.14	X	17
Potamogeton polygonifolius	1.71	4.69	X	16
Potamogeton praelongus	7.81	8.83	X	17
Potamogeton pusillus	7.47	8.45	X	14
Potamogeton trichoides	7.24	9.31	X	14
Potamogeton x bottnicus	6.41	8	X	15
Potamogeton x cooperi	6.07	6.87	X	17
Potamogeton x fluitans	6.51	5.51	X	16
Potamogeton x gessnacensis	3.88	5.97		16
Potamogeton x lanceolatus	4.24	6.5	X	17
Potamogeton x nitens	6.17	5.45	X	17
Potamogeton x olivaceus	5.44	6.41	X	17
Potamogeton x salicifolius	6.36	7.01	X	17
Potamogeton x sparganifolius	3.87	3.78	X	16
Potamogeton x suecicus	6.02	6.31	X	15
Potamogeton x zizzii	4.19	3.75	X	16
Potentilla palustris	2.88	5.04		
Racomitrium aciculare	1.89	3.37	X	22
Ranunculus (sect Batrachian) sp or hybrid indet	7.33	7.75	X	18

Table 1: List of river macrophyte taxa and associated information for the calculation of the values for the parameters

Column 1	Column 2	Column 3	Column 4	Column 5
Taxon	**River macrophyte nutrient index score (R)**	**River macrophyte hydraulic index score (H)**	**Taxa listed in Column 1 which are not helophytes (x)**	**Macrophyte functional group number**
Ranunculus aquatilis var aquatilis	5.67	6.63	X	18
Ranunculus aquatilis var diffusus	7.65	7.74	X	18
Ranunculus circinatus	9.42	8.85	X	5
Ranunculus flammula	2.56	4.39		
Ranunculus fluitans	7.97	7.44	X	18
Ranunculus hederaceus	5.47	5.64		
Ranunculus omiophyllus	3.43	4.78	X	11
Ranunculus peltatus var baudotii	9.06	7.79	X	18
Ranunculus peltatus var peltatus	6.22	6.71	X	18
Ranunculus penicillatus	8.25	7.64	X	18
Ranunculus penicillatus ssp. penicillatus	6.29	6.35	X	18
Ranunculus penicillatus ssp. pseudofluitans	7.92	7.53	X	18
Ranunculus penicillatus subsp vertumnus	5.87	6.51	X	18
Ranunculus sceleratus	9.86	8.43		
Rhodochorton violaceum	4.14	4.35		
Riccardia chamaedryfolia	4.91	6		
Riccardia multifida	5.25	6.74		
Riccia sp.	4.86	9	X	1
Rivularia	4.77		X	20
Rorippa amphibia	9.20	8.51		
Rorippa nasturtium-aquaticum	8.42	8.08		
Rorippa palustris	7.32	7.45		
Rumex hydrolapathum	8.65	8.11		
Sagittaria sagittifolia	9.24	9.32	X	12
Scapania sp. (aggregated)	2.14	3.83	X	23
Scapania subalpina	3.21	2.18	X	23
Scapania uliginosa	2.66	1.97	X	23
Scapania undulata	2.05	4	X	23
Schistidium agassizii	2.23	3.45		
Schistidium rivulare	5.16	3.48		
Schoenoplectus lacustris	8.44	8.83	X	13
Schoenoplectus tabernaemontani	7.43	8.02		

Table 1: List of river macrophyte taxa and associated information for the calculation of the values for the parameters

Column 1	Column 2	Column 3	Column 4	Column 5
Taxon	**River macrophyte nutrient index score (R)**	**River macrophyte hydraulic index score (H)**	**Taxa listed in Column 1 which are not helophytes (x)**	**Macrophyte functional group number**
Scirpus sylvaticus	6.45	6.85		
Scorpidium revolvens	4.29	5.01		
Sium latifolium	7.08	7.93		
Sparganium angustifolium	2.26	4.81	X	13
Sparganium emersum	8.32	8.58	X	13
Sparganium erectum	8.34	8.26		
Sparganium natans	3.59		X	13
Sparganium sp.	4.11			
Sphagnum denticulatum	4.84			
Sphagnum sp(p)	1.07	2.92		
Spirodela polyrhiza	8.99	8.9	X	1
Spirogyra[A]	6.45	6.37	X	19
Stigeoclonium tenue[A]	6.62	5.69	X	19
Stigonema sp	4.32	6.62	X	19
Tetraspora lubrica/gelatinosa	6.72	6.07	X	3
Thamnobryum alopecurum	4.22	4.89	X	21
Tolypothrix penicillata	2.96	3.35	X	3
Triglochin palustris	4.07	5.17		
Typha angustifolia	7.57	9.05		
Typha latifolia	8.87	8.42		
Ulva flexuosa[A]	9.52	8.43	X	19
Utricularia intermedia	2.74		X	9
Utricularia minor	3.77		X	9
Utricularia sp	3.23		X	9
Utricularia vulgaris s.l.	3.72		X	9
Vaucheria sp(p) [A]	8.41	7.6	X	19
Veronica anagallis-aquatica	8.45	8.25		
Veronica beccabunga	7.31	6.99		
Veronica catenata	9.32	8.48		
Veronica catenata x anagallis-aquatica	8.34	7.92		
Veronica scutellata	2.35	4.6		
Zannichellia palustris	9.01	8.43	X	15
Zygnematalean alga[A]	6.45		X	19

Table 2: Identification of taxon cover values for macrophyte taxa

Column 1	Column 2	Column 3

Percentage cover range (% of channel area)	Taxon cover value	Mid point percentage
< 0.1	1	0.05
0.1 < 1	2	0.5
1 < 2.5	3	1.7
2.5 < 5	4	3.8
5 < 10	5	7.5
10 < 25	6	17.5
25 < 50	7	37.5
50 < 75	8	62.5
≥ 75	9	87.5

Annex 2: Worked example

The following data were obtained from a survey of a large, lowland calcareous river. The first column has the taxon name, the second column shows the taxon cover value of that taxon in the sample; the third and fourth columns have the RMNI and RMHI scores respectively for that taxon (see Table 1), the fifth column records whether the taxon is a true aquatic (A_TAXA = 1) or not (A_TAXA = 0) , the sixth column shows the functional group to which the taxon, if aquatic, belongs, and the final column indicates the percentage cover associated with any taxon classified as a green filamentous alga.

Species	Taxon cover value	River macrophyte nutrient index score	River macrophyte hydraulic index score	A_TAXA	Macrophyte functional group number	ALG % cover
Apium nodiflorum	3	8.64	8.08	1	8	
Callitriche obtusangula	1	8.04	7.98	1	6	
Cladophora glomerata	4	7.50	6.84	1	19	3.8
Fontinalis antipyretica	2	5.40	5.95	1	21	
Hildenbrandia rivularis	4	6.03	6.07	1	20	
Lemna minor	2	8.80	8.59	1	1	
Oenanthe crocata	1	6.22	6.48	1	8	
Phalaris arundinacea	6	7.52	7.24	0		
Phragmites australis	3	7.70	8.94	0		
Ranunculus fluitans	8	7.97	7.44	1	18	
Rumex hydrolapathum	1	8.65	8.11	0		

In addition, the following environmental data were derived:

Variable	Value
Site altitude	45 metres
Slope (S)	0.9 metres km^{-1}
Distance to source (D)	58.5 kilometres
Altitude of source (h)	140 metres

Alkalinity (A)	217 mg/l $CaCO_3$
Northing (N)	128728

RMNI

The RMNI is calculated as follows:

1. Calculate taxon cover value × river macrophyte nutrient index score for all relevant taxa present in the sample
2. Sum the results of step 1, above = 263.28
3. Sum the taxon cover values for all relevant taxa present in the sample = 35
4. Calculate the observed value of RMNI as 263.28 ÷ 35 = 7.52

The reference value is calculated using the applicable equation in section 3.2. This results in a reference value of 6.36.

EQR_{RMNI} = (7.52 – 10) / (6.36 – 10) = 0.68.

EQR_{RMNI} is adjusted using the applicable equation in section 3.4, to give $^{A}EQR_{RMNI}$ = 0.57

RMHI

The observed value of RMHI is calculated as follows:

1. Calculate taxon cover value × river macrophyte hydraulic index score for all relevant taxa present in the sample
2. Sum the results of step 1, above = 257.36
3. Sum the taxon cover values for all relevant taxa present in the sample = 35
4. Calculate the observed value of RMHI as 257.36 / 35 = 7.35

The reference value is calculated using the applicable equation in section 3.2. This results in a reference value of 6.85.

EQR_{RMHI} = (7.35 – 10) / (6.85 – 10) = 0.84

EQR_{RMHI} is adjusted using the applicable equation in section 3.4, to give $^{A}EQR_{RMHI}$ 0.79.

Functional diversity

The observed number of functional groups (NFG) for this river is 7. There are 8 aquatic plant taxa because the helophytes *Phalaris arundinacea*, *Phragmites australis* and *Rumex hydrolapathum* are excluded. The remaining species belong to different functional groups, except *Oenanthe crocata and Apium nodiflorum* which share the same functional group. Consequently, there are seven functional groups.

The reference value for NFG is calculated using the applicable equation in section 3.2. This results in a reference value of 5.02.

$EQR_{NFG} = Log_{10}$(observed value of NFG + 1) / Log_{10}(reference value for NFG + 1) = 1.16

EQR_{NFG} is adjusted using the applicable equation in section 3.4, to give $^{A}EQR_{NFG} = 1$

Number of taxa

The observed number of aquatic plant taxa (NTAXA) is 8 as helophytes are excluded.

The reference value for NTAXA is calculated using the applicable equation in section 3.2. This results in a reference value of 6.5.

$EQR_{NTAXA} = Log_{10}$(observed value of NTAXA + 1) ÷ Log_{10}(reference value for NTAXA + 1) = 1.09

EQR_{NTAXA} is adjusted using the applicable equation in section 3.4, to give $^{A}EQR_{NTAXA} = 1$

Algal cover

The observed cover of green filamentous algae (ALG) is 3.8%

The reference value for ALG is fixed at 0.05.

EQR_{ALG} = (observed value of ALG -100) ÷ (reference value for ALG - 100) = 0.962

EQR_{ALG} is adjusted using the applicable equation in section 3.4, to give $^{A}EQR_{ALG} = 0.75$.

The complete results for this river are, therefore, as follows:

Parameter	Observed value	Reference value	EQR	^{A}EQR
RMNI	7.52	6.36	0.68	0.57
RMHI	7.35	6.85	0.84	0.79

NFG	7.00	5.02	1.16	1
NTAXA	8.00	6.5	1.09	1
ALG	3.8	0.05	0.96	0.75

Calculating the EQR for the combined parameters

Step 1:
The smaller of the values of ${}^{A}EQR_{RMNI}$ and ${}^{A}EQR_{RMHI}$ is 0.57 (the value for ${}^{A}EQR_{RMNI}$). ${}^{A}EQR_{NTAXA}$ and ${}^{A}EQR_{NFG}$ both have values of 1.

The ecological quality ratio for the combined composition and diversity parameters ($EQR_{C\&D}$) is calculated using the applicable equation in section 3.5:

$EQR_{C\&D} = [(1 \times 0.6) + 0.57] / (1 + 0.6) = 0.73$

Step 2:
The value $EQR_{C\&D}$ is compared with ${}^{A}EQR_{ALG}$. Since the value of $EQR_{C\&D}$ is < ${}^{A}EQR_{ALG}$ no further adjustment of $EQR_{C\&D}$ is required. Therefore $EQR_{LEAFPACS} = 0.73$.

$EQR_{LEAFPACS}$ for the waterbody would be reported as the mean of $EQR_{LEAFPACS}$ values for each individual site surveyed.

Annex 3: Further Reading

Willby, N.J., Pitt, J & Phillips G. L. (2009). Development of a system for the classification of rivers and lakes in the UK using aquatic macrophytes. Part 2 Rivers. Environment Agency Science Report in preparation.